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Rotary Veneer Bentwood as a Sustainable Material for Responsible Furniture Production

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ABSTRACT

The use of spindleless rotary peeling technology has revolutionized the processing of smaller diameter wood species like rubber wood and acacia, which were previously unable to be turned into rotary veneers using traditional methods that only accommodated larger diameter wood. This article is intended to provide valuable insights, particularly for furniture designers, on how to utilize environmentally friendly and efficient raw materials that retain the beauty of wood through 4 design cases (2 solid wood chair design & 2 bentwood chair design). The article was created through a descriptive analysis method, iterative design method, and material driven design method, which involved direct study and furniture design of mass-produced wooden furniture made from solid wood and prototype-scale bentwood furniture, as well as surveys of factories producing solid wood furniture and rotary veneers, and factories producing bentwood furniture. With comparison of all 4 designs, it is concluded that manufacturers can achieve a more sustainable, efficient, and environmentally friendly option for material, parts, and hardware usage by using rubber wood rotary veneer bentwood as the main material. Design, in terms of 3D production, rendering, technical drawings, assembly instruction also take less time to produce compare to furniture designs in solid wood material. In short, the use of rotary veneer bentwood is highly encouraged over solid wood, to support Sustainable Development Goal (SDG) 12 on responsible production.

INTRODUCTION

Veneer refers to a slender sheet of wood, typically with a thickness of 1-4 mm, obtained by rotating peeled wood. Other types of veneer may have different thickness, such as cocoveneer with 2.5-6mm layer thickness. This definition excludes other types of veneer such as sliced or sawed veneers [1]. Efficiently processing small-diameter trees into valuable wood products is currently limited, as conventional methods have low product recovery rates for such trees. This means that large forest areas and plantations are underutilized and considered low-quality. Veneer production is common in many countries but has been hindered by high capital investment and large-scale operations, particularly in developing countries. However, in the past decade, new technologies have emerged that show significant potential for developing veneer processing operations using small-diameter trees grown by farmers [2]. Spindleless lathes have made it possible to produce veneer sheets from small-diameter wood efficiently, with remaining core sizes of 20 to 50 mm. Compared to traditional veneer lathes, the capital cost of spindleless lathes is generally less than 10%, making them more accessible in developing countries. Veneer production offers a unique opportunity to increase the value of trees planted by smallholder farmers, creating new industries and job opportunities in developing countries. The modern spindleless veneer peeling technology represents a game-changing opportunity, revolutionizing the veneer production economy and subsequently, the production of veneer-based products such as plywood and laminated veneer wood.

Historically, only the largest and highest quality wood was deemed suitable for

making veneers [3], leading to low yield and high costs due to expensive wood and veneer processing. However, new technology with low capital costs (less than 20% of traditional spindle lathes) can now produce high-quality veneers from small diameter wood, resulting in yields above 75% [4]. This has brought about a permanent change to the veneer and plywood production economy, presenting enormous opportunities for forest owners and wood processors to extract more value from low-quality wood resources. In the future, veneer producers will prioritize small-diameter and fast-growing plantation logs, as well as small-diameter native forest timbers that can be supplied in significant volumes and delivered to processors cost-effectively. This will enable veneer processors to compete in an increasingly challenging market dominated by low-cost suppliers.

In numerous countries, low-quality hardwood plantations and native forest timber resources are mainly used for low-value applications like wood chips, landscaping, and bioenergy. However, with the potential for higher returns on investment and increased employment opportunities, these resources could be used to produce higher value products such as veneer-based engineered wood products. In recent years, there has been a rise in the growth of trees for rotary peeling purposes worldwide, particularly in Southeast Asia, with China and Vietnam taking the lead in processing very young plantation hardwoods using this technology [5]. The benefits of veneer-based products are a key driver of this growth. Additionally, technological improvements in rotary peeling equipment have allowed for efficient processing of very small and young plantation hardwoods, with diameters of less than 15 cm (and from trees less than 5 years old), including rubber, acacia, and coconut wood. The success of these operations has been such that rotary peeling mills have competed with pulp timber enterprises for the same quality timber resources in some areas.

Veneer-based products offer various advantages over other options such as sawing. Compared to sawmill processing, rotary peeling yields much greater product from the same size and quality of wood, due to the absence of sawdust or wood chips. This improved yield has a significant impact on the return on investment of wood processors. Veneers can also be dried more quickly, reducing energy costs and storage issues compared to solid wood products [6].

Amidst the destructive impacts of global warming and limited resources, there is a growing focus on promoting sustainable practices in the furniture industry. Previous research indicates that this sector significantly contributes to worldwide trade, utilizing a substantial amount of raw materials, releasing pollutants, and generating extensive waste. Each day witnesses the production, consumption, and disposal of millions of furniture items, exacerbating resource depletion and waste accumulation. These unsustainable production and consumption patterns underpin the prevailing linear economy, characterized by the acquire-make-waste cycle. Given this perspective, the overhaul of furniture production and consumption holds particular significance in advancing environmental conservation and fostering social sustainability [7].

This article aims to offer furniture designers valuable information about the potential of rotary veneer as a high-value engineered wood product that can be utilized in various applications, including furniture production. A comparative case study of the production of solid wood furniture and rotary veneer (bentwood) is presented to demonstrate the

suitability of rotary veneer for furniture products. Four chairs (2 solidwood chairs, and 2 bentwood chairs) are designed and studied to showcase the advantages and disadvantages of each. Furthermore, this article aims to advise wood producers to focus on producing more high-value raw materials, given the relatively premium quality of wood in Indonesia.

LITERATURE REVIEW

Furniture

In many industrialized nations, the furniture industry stands as a foundational sector, contributing 2% to 4% of the manufacturing output value [8]. The furniture industry operates fundamentally as an assembly sector, utilizing diverse raw materials in its production processes [9]. Consequently, the environmental consequences stemming from furniture are largely dictated by these materials, with previous research indicating that one-third of all materials extracted from the Earth are employed in the furniture industry [10]. Wood serves as the primary raw material in furniture production. However, current consumer behavior trends lean towards reducing the service cycle of products, particularly in the business furniture sector. This trend is characterized by the replacement of old furniture with new pieces before they reach the end of their functional life, driven by aesthetic considerations and image changes [12]. Consequently, the furniture industry faces a significant waste challenge. Throughout the lifecycle, from raw material acquisition to manufacturing and waste disposal, each stage contributes to the transfer of matter or energy to the natural environment. In accordance with the 17 UN Sustainable Development Goals (SDGs), the furniture industry contravenes SDG 12, responsible consumption and production (Goal 12 target 3, aiming to achieve sustainable management and efficient use of natural resources by 2030). Therefore, ensuring the sustainable development of the furniture industry in the current context is paramount.

Veneer

Innovations in the engineering of veneer-based products have led to the creation of stable and uniform materials that can be produced in a variety of sizes and consistently high quality. This is in contrast to solid wood products, which are often graded based on their defects and inconsistencies. Veneer-based products have the advantage of being able to conceal defects and provide a consistent and uniform supply of high-quality products. The process of rotary veneer processing also presents a unique opportunity to utilize low-quality wood that may not be suitable for other processing methods, such as sawing. Numerous techniques exist to rectify defects in veneers, including composing, scarf-jointing, patching, and splicing, all of which are employed to optimize the production of veneers [13]. During the repair process, the veneers are strategically placed in the center of the sheet, whether it be on plywood or LVL, to ensure complete coverage and preserve the product's appearance (only the finest quality veneers are used on the outermost layer) [14]. Simply say, lower grade veneers (e.g. grade D-F) can be hidden in the middle of the sheet, while higher grade veneers can be the face veneers (grade A-B) [15]. This practice allows maximum use of defect or lower quality materials, which is more sustainable in the long term, provided not much high quality wood is available these days.

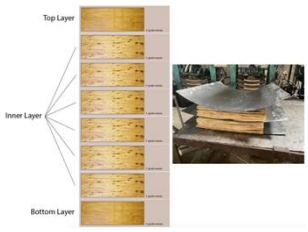

Fig. 1. Veneer Layering Illustration with Grading Consideration

Rotary Veneer Material

As wood becomes scarcer globally, wood producers are turning to smaller trees, such as rubber wood and acacia wood, which are popular in the Vietnamese furniture industry. Young plantation hardwoods are particularly suitable for veneer-based products, and there has been an increase in the number of rotary veneer processing facilities worldwide that successfully cultivate these trees. Spindleless rotary technology has also made it possible to process small-diameter wood. In the production of solid wood furniture and bentwood, both rubber wood and acacia wood are commonly used. Rubber wood, a medium density light-colored wood similar to ash or maple, grows in tropical regions of Southeast Asia, often from rubber plantations. It is considered environmentally sustainable because it is harvested after the latex production decreases, which extends its life cycle. This wood is popular due to its fast-growing nature, making it a more eco-friendly option than other solid woods. Rubber wood is commonly used as a raw material for furniture production in Vietnam due to its affordability and availability. This wood can be used as a material for both solid furniture and bentwood [16]. Approximately 2 million hectares of acacia plantations exist worldwide, encompassing three species: Acacia auriculiformis, Acacia crassicarpa, and Acacia mangium, with Vietnam accounting for 1.1 million of these plantations, boasting a rapid 5-10 year growth cycle [17]. The fast growth cycle of acacia wood is a key factor making it a popular raw material for furniture. Larger acacia wood is usually reserved for construction, furniture, and other applications while smaller wood is employed for paper and MDF production. In Vietnam, there are more than 3 million hectares of plantation forests consisting of a variety of fast-growing species like acacia, rubber wood, eucalypts, and pine, and while originally established to provide wood chips for the paper and pulp industry, there has been a growing interest in converting these plantations into higher value export products like veneer-based products for furniture components, laminated veneer wood, and other applications [18].

Solid Wood Furniture Disadvantages

It is clear that solid wood furniture requires many parts, joints, and hardware in order to stand into one furniture unit. There are quite a lot of examples of parts needed for a dining chair, including a seat, front legs, rear legs, apron, seat frame, backrest, and others depending on the design. The types of joints used also vary including mortise tenon, butt, mitre, rag, dovetail, and so on depending on construction and design. As for the hardware needed, especially to produce knock-down construction, there are quite a lot

of them, such as long bolts, short bolts, allen bolts, screws, allen keys, spring washers, flat washers, and so on. The more complex parts, connections, and hardware, will complicate the design process, sampling process, production, QC, and all related processes [19].

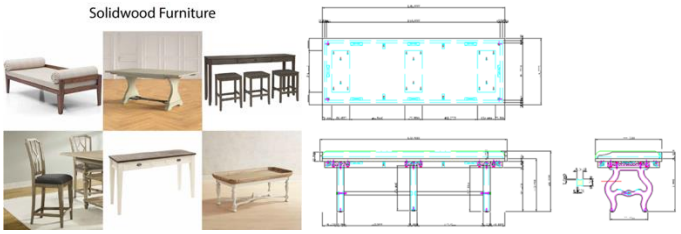

Fig. 2. Types of solid wood furniture & Complex solid wood furniture computer drawing (orthogonal view only, not included parts drawing)

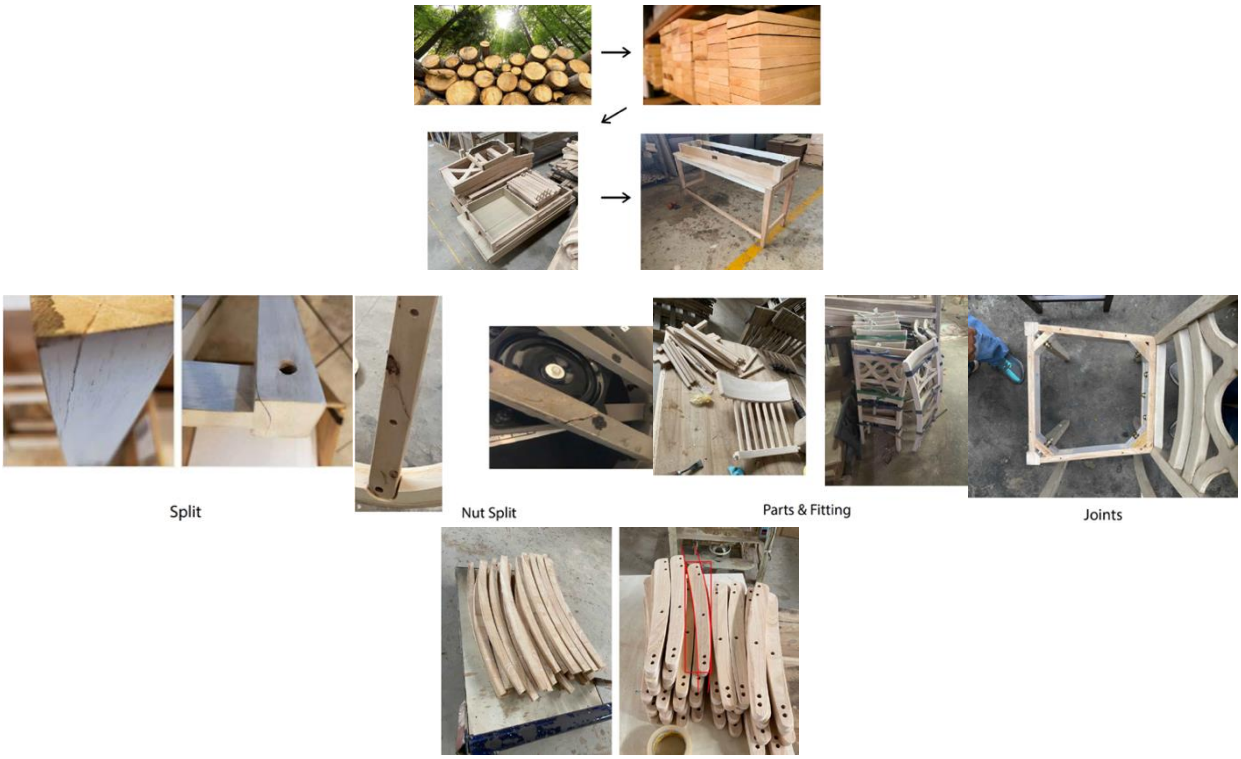

Fig. 3. Solid wood furniture brief production process & Issues with solid wood furniture

Bentwood Furniture Advantages

Brief production process of bentwood furniture includes veneer preparation, veneer cutting, molding, pressing, and finishing, as illustrated below [20]. Typically, not much hardware and parts are involved in bentwood furniture making, unlike those in solid wood furniture.

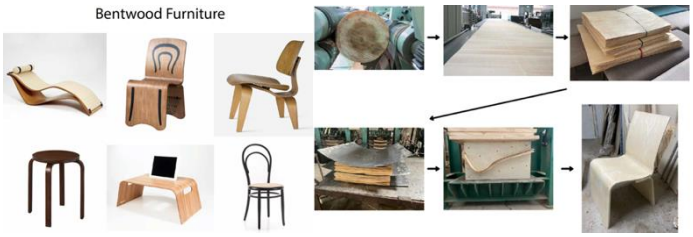

Fig. 4. Bentwood furniture & Brief production process

METHODS

This article was created using descriptive analysis techniques, iterative design method, material design driven method, including direct observation and study of the production of mass-produced solid wood furniture and prototype-scale furniture made from rubber wood veneer (bentwood). Researcher limits the research in veneer sheet made into bentwood form, steamed bentwood is excluded in this research. Chair is the foundation of furniture design, and the most sellable items in furniture retail, making it a solid ground when choosing the design category for case studies. Four designs were created (two in solidwood form, and two in veneer bentwood form, all of them are in standard dining chairs height). These 4 designs will be analysed based on parameters such as: furniture parts number, connection point number, hardware quantity, labor intensive process, computer modeling time, and complexity of assembly process. Surveys, designs, prototyping were conducted in both solid wood furniture factories and factories producing rotary veneer and bentwood. The research was undertaken in Vietnam factories. Additionally, literature from reliable sources was reviewed to provide further insights.

RESULT AND DISCUSSION

The life cycle phases of sustainable furniture encompass eight stages, which include design, procurement, manufacture, transportation, distribution, maintenance, recycling, and disposal. This study will specifically emphasize the design stage and the initial step of manufacturing, known as the prototyping stage.

During the design stage, the life cycle initiates with conceptual design, involving tasks such as information collection, idea generation, design drawings, computer-aided design, innovation, and new product development. Choices made at this juncture hold considerable significance as they exert an influence on the entire life cycle, spanning from manufacturing to the product's end-of-life [21]. This is because the selection of product materials and production techniques in the design phase determines the release of pollutants and wastes, energy consumption during use, and the ease with which components can be reused in subsequent usage and manufacturing cycles [22,23]. It is estimated that 70% of the environmental impacts arising from products are established during the design stage [24]. Consequently, the majority of a product's sustainability characteristics can be attributed to the early design phase [25].

Two detail data of solidwood chair designs are not presented as it is a confidential company data for production purpose, only final photo is allowerd (as in 4.3, Table 1.). The other two bentwood chair designs are presented below.

Project Description

Design 1, a stylish dining-sized chair that serves as a canvas for personal expression in chair design evolution. Its surface features various style graphics, allowing users to choose based on their preferences. Inspired by iconic chairs like Thonet and Napoleon, Design 1 blends tradition with contemporary flair. Beyond aesthetics, it prioritizes comfort with a curved back for lumbar support during extended sitting. Additionally, a unique metallic waveform storage beneath the seat provides convenient access to favorite magazines or novels, combining form and function seamlessly.

Fig. 5. Bentwood Chair Design 1

Design Challenge

Revolutionizing postmodernism in furniture, this contemporary chair seamlessly incorporates iconic images from the modernism era without overpowering its overall design. It aims for a lightweight and comfortable feel, using minimal tools and hardware while ensuring robust construction for user safety. Beyond its expressive platform, the chair prioritizes its fundamental function, aiming to provide both comfort and ease of use.

Fig. 6. Design Alternatives to Bentwood Chair Design 1

Design Solution

Transforming 3D shapes of classic chairs into 2D graphics, Design 1 carefully integrates them onto its surfaces, ensuring a harmonious standalone or set design. Leveraging Laminated Veneer Lumber's flexibility, it molds to the human back's contours for maximum comfort with minimal material use. This yields a sleek, organic design offering ample surface area for user support. The space between slim front and rear legs is utilized for a metal storage feature, not only providing extra storage but also reinforcing the overall structure. Opting for metal ensures durability, especially when accommodating various items, heavy or light, enhancing both function and strength.

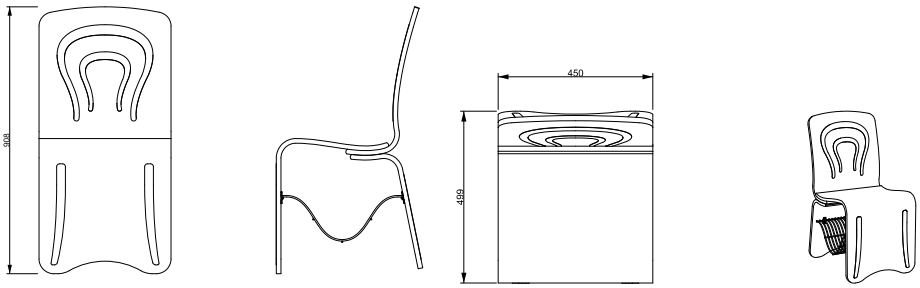

Fig. 7. Dimensions of Bentwood Chair Design 1

Design Impact

Introducing Design 1, a versatile seating solution for users to relax while engaging in activities like reading, watching movies, or working. It features a convenient storage space below the seat for books or belongings. Prioritizing ease-of-use, comfort, and serviceability, It has only four removable and replaceable parts, extending its lifespan. Crafted with real wood veneer for the main body parts and a durable, recyclable metal storage, this chair is eco-friendly, offering a sustainable seating option.

Fig. 8. Prototyping Process for Bentwood Chair Design 1

Bentwood Design Concept 2

Project Description

Design 2, is a versatile stool designed for interactive pet experiences indoors. It features a unique shelf under the seat for pets or storage, customizable openings on the stool legs, and an optional low back-rest with a handle for added functionality and convenience.

Fig. 9. Bentwood Chair Design 2

Design Challenge

Revamp home furniture with integrated pet-housing for both young and adult users. The design prioritizes simplicity, user safety, and easy assembly with minimal tools.

Design Solution

Design 2 employs a 100% veneer bentwood manufacturing process, providing strength without bulky design. The freedom in veneer-laminating allows for unconventional shapes and efficient linking of stool parts, reducing the need for additional equipment for the end-user's benefit.

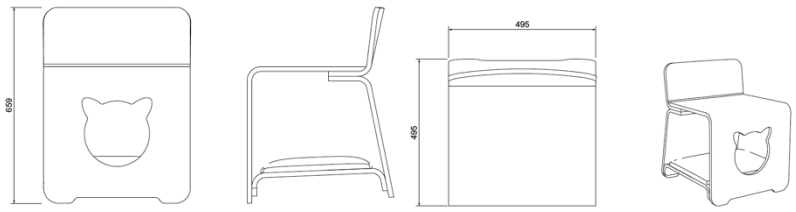

Fig. 10. Dimensions of Bentwood Chair Design 2

Design Impact

Design 2 is a versatile furniture piece that serves as a home for pets, offers extra storage, and introduces a unique multipurpose experience. Designed with simplicity, modularity, and sustainability in mind, Design 2 is crafted with 100% real wood veneer, promoting recyclability and environmental friendliness. Its parts are easily removable and replaceable for extended product lifespan.

Fig. 11. Prototype of Bentwood Chair Design 2

Comparison between Solid Wood Furniture and Bentwood Furniture

Table 1. Solid Wood Furniture vs Bentwood Furniture Comparison

Chair A&B (solid wood)

Chair C&D (bentwood)

Parameter	A	B	C	D
Furniture Parts number	24	19	4	5
Wood joints number	47	23	11	6
Hardware quantity	59	57	11	18
Labor intensive process	high	high	moderate	moderate

Computer modeling & rendering time	Est. 6 hours	Est. 5 hours	Est. 2 hours	Est. 2 hours
Assembly Instruction	complex	complex	easy	easy
Assembling Time	moderate	moderate	quick	quick

In solidwood dining chairs, many furniture parts are needed to assemble a single chair, including seat frame, back rest, back leg, front leg, apron, and stretcher. To join all these pieces together, many wood joints and hardwares are needed, mainly because almost all furniture in retailers today are in knock-down system. In short, solid wood furniture is much more complex from design process, material processing to manufacturing, while veneer bentwood furniture is much more simple in similar fashion.

CONCLUSION

Rotary veneer converted to bentwood furniture is a more environmentally friendly, sustainable, efficient option in the use of materials and hardware. The advantages of using rotary veneer as raw material for furniture are:

- Increased yield and value of forest resources. Rotary veneer can be produced from low-quality wood resources that are not suitable for traditional sawn timber products. In addition, the veneer yield obtained is usually about 2 to 6 times more than the rotary peeling process compared to the sawing process, especially when using small-diameter wood sources. The sawn yield (sawn timber) usually only gives a yielf of about 35%, while in rotary veneer it can be up to 70%.
- More predictable product outcomes, faster production, and more possible product dimensions. Products based on rotary veneer can be produced in greater length, width, and thickness compared to products produced by traditional sawmills.
- Unlike solid wood products, veneer-based products can tolerate defects by upgrading veneers. The appearance of imperfect veneers that have gone through the upgrading process can also be hidden by slipping the veneer in the middle of the sheet before the veneer is pressed into bentwood.
- Use of materials that are much more efficient than solid wood
- Significantly reduced waste (scraps, sawdust, others) compared to solid wood furniture production waste
- Much better working conditions because not much sawdust is produced
- Reduction in the number of parts, the number of connection points, the number of hardware used significantly
- A more sleek and modern product look
- Significantly reduce time in furniture computer modeling and rendering setting
- Significantly reduce the number of labor, electricity cost, range of machineries, during production process
- Indonesia furniture design landscape still surrounds in solid wood form. With all source of beautiful woods come from Indonesia, bentwood furniture has not been widely developed
- In the current business landscape, design plays an increasingly prominent role, with its implementation proving crucial for the created value and management

possibilities. Design has the capacity to revolutionize a company's image, streamline costs, and foster innovation in products and services. It aids in upholding product quality across functional, production, economic, and socio-cultural dimensions while enhancing the competitiveness of enterprises. The stakeholders, or designers, engaged in design activities play a pivotal role in this phase, and their creative latitude can significantly influence the materials and characteristics of the final product. During the design process, designers have the autonomy to choose and define the material, formal, and practical aspects of furniture, thereby impacting the emotional response and subsequent consumer behavior. For instance, designers can heighten consumer awareness of environmental concerns through the design of websites, advertisements, brochures, and other promotional materials, facilitating communication about the benefits of using eco-friendly products. Hence, the value derived from design activities extends beyond commercial and material gains, encompassing ecological values and social responsibility.

However there are some limitations in the research, as discussed below:

- In the manufacturing of wood-based products (including veneer bentwood), adhesives are employed, potentially leading to pollution. The utilization of environmentally friendly adhesives derived from forests has the potential to broaden opportunities for extending the life cycles of forest products through reuse and recycling, though it has not been executed in this research.
- Ensuring an effective guarantee for maintenance services proves challenging. On a typical basis, consumers opt to purchase new furniture every three years. The primary motivation behind such purchases is the necessity to replace furniture that has become worn or damaged. The predominant issue arising after three years of furniture use is the deterioration of parts, material wear, and the absence of support from furniture companies in terms of repairs and spare parts services for customers. Consequently, the accumulation of end-of-life products becomes problematic, posing difficulties in management, elimination, and destruction. This problem applies for all types of furniture (both solid and bentwood).

This conclusion results from research activities undertaken in Vietnam on bentwood furniture made of local rubber wood as the main source of veneer. Other types of veneer may vary slightly in terms of conclusion, although generally should have similar results.

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